Evaluating the Soil Leaching Pathway under WAC 173-340-747

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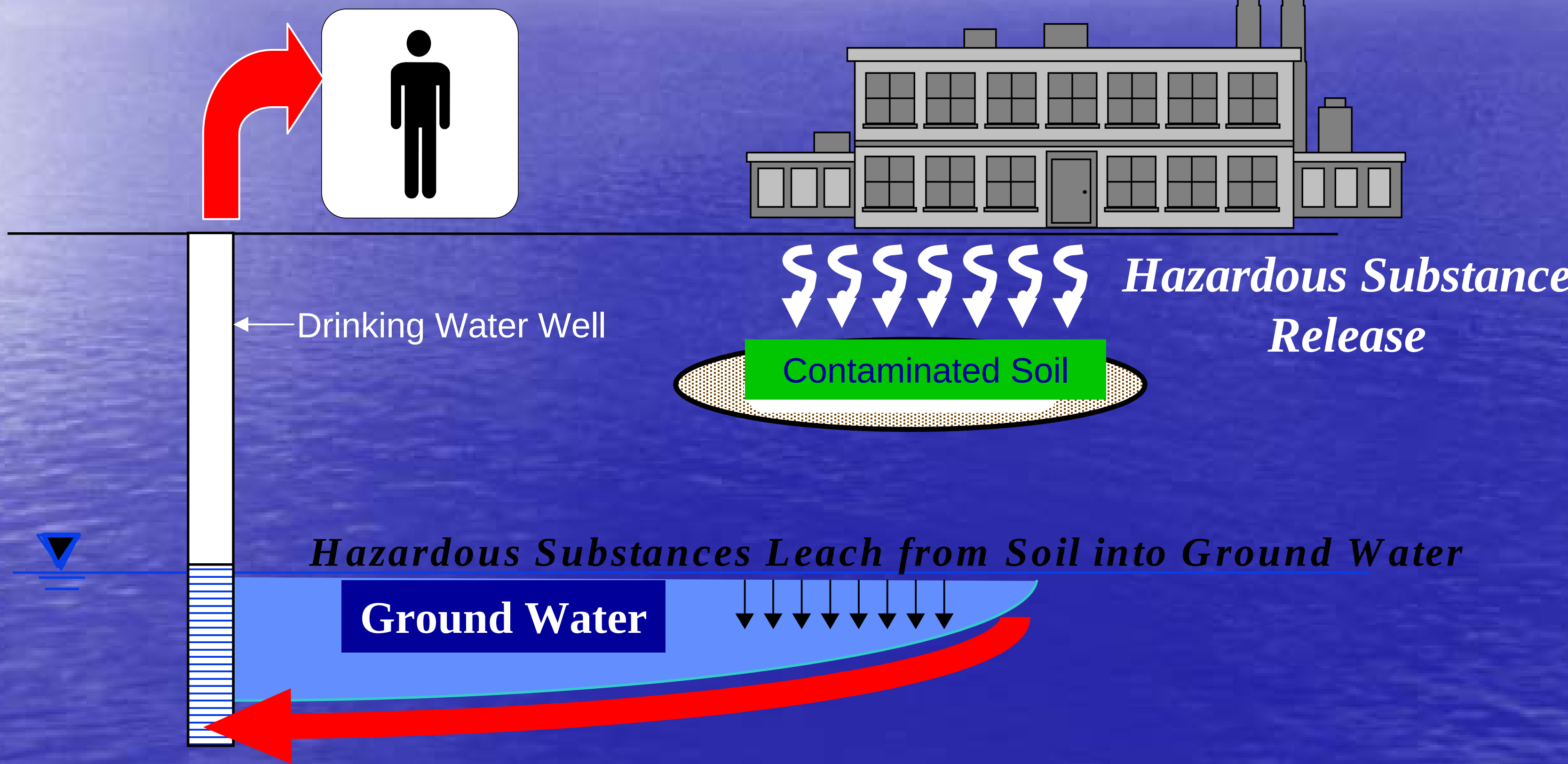
For additional information, see our web page:
http://www.ecy.wa.gov/programs/tcp/cleanup.html

Methods for Evaluation of the Soil Leaching Pathway under Section 747

- 3-Phase Partitioning Model
- 4-Phase Partitioning Model
- Other Fate / Transport Models
- Leaching Tests
- Empirical Demonstration

Conceptual Site Model: Soil to Groundwater Exposure Pathway

Human Exposure = 1-2 Liters of Water per Day



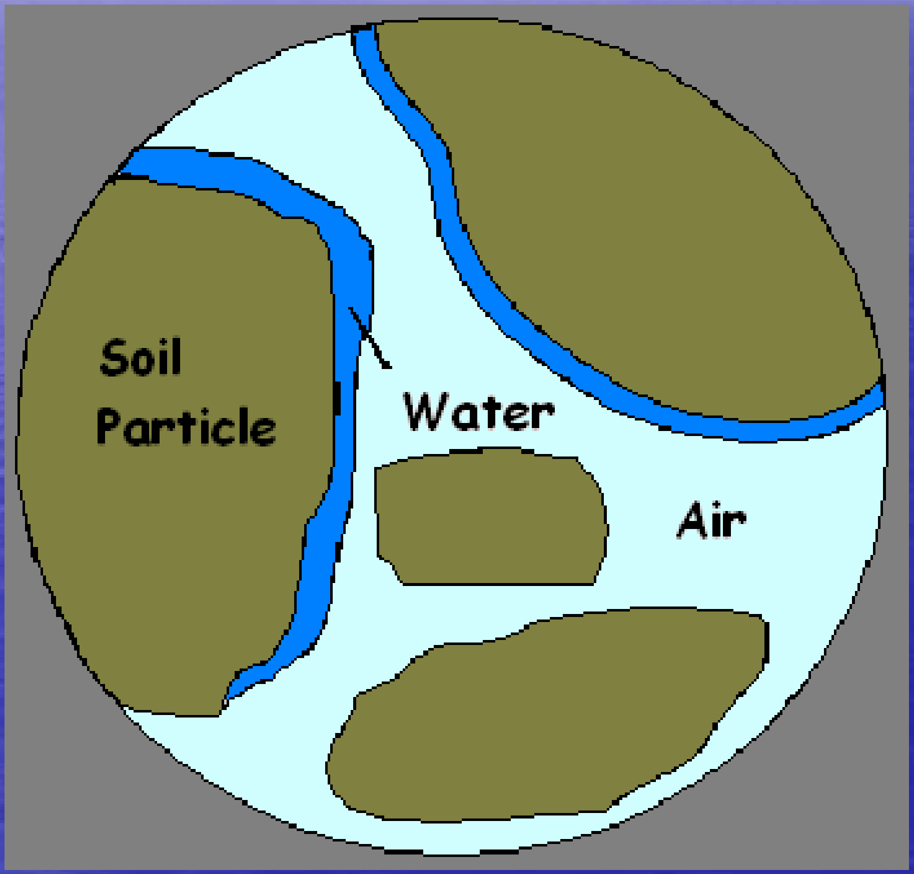
Hazardous Substances Migrate in the Direction of Ground Water Flow

Section 747 Criteria

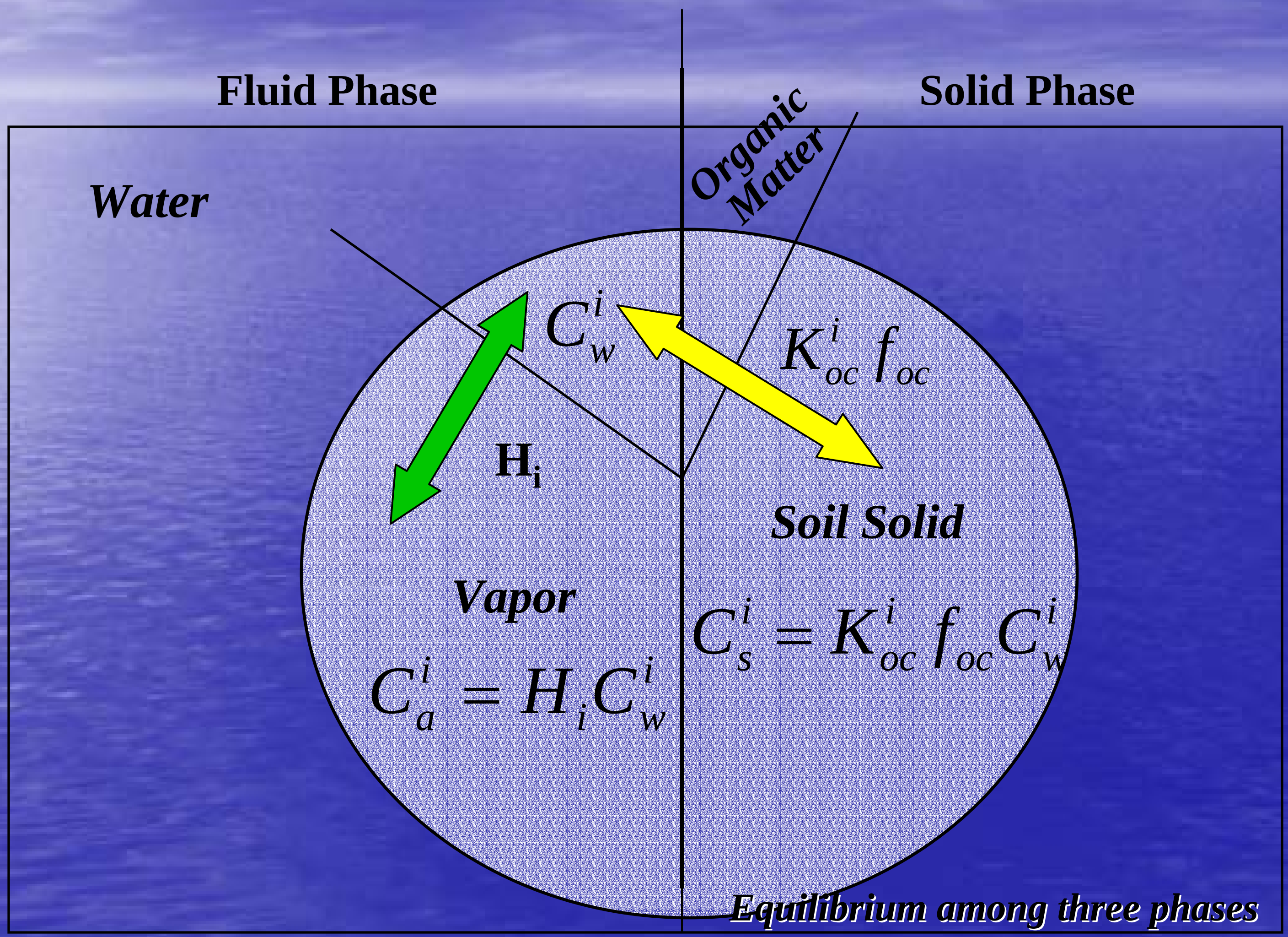
Soil concentration considered protective if:

- Section 720 ground water cleanup level has not been exceeded, and
- Non-aqueous phase liquids (NAPL) are not present on or in ground water.

3-Phase Soil Conceptual Model



3-Phase Equilibrium Partitioning

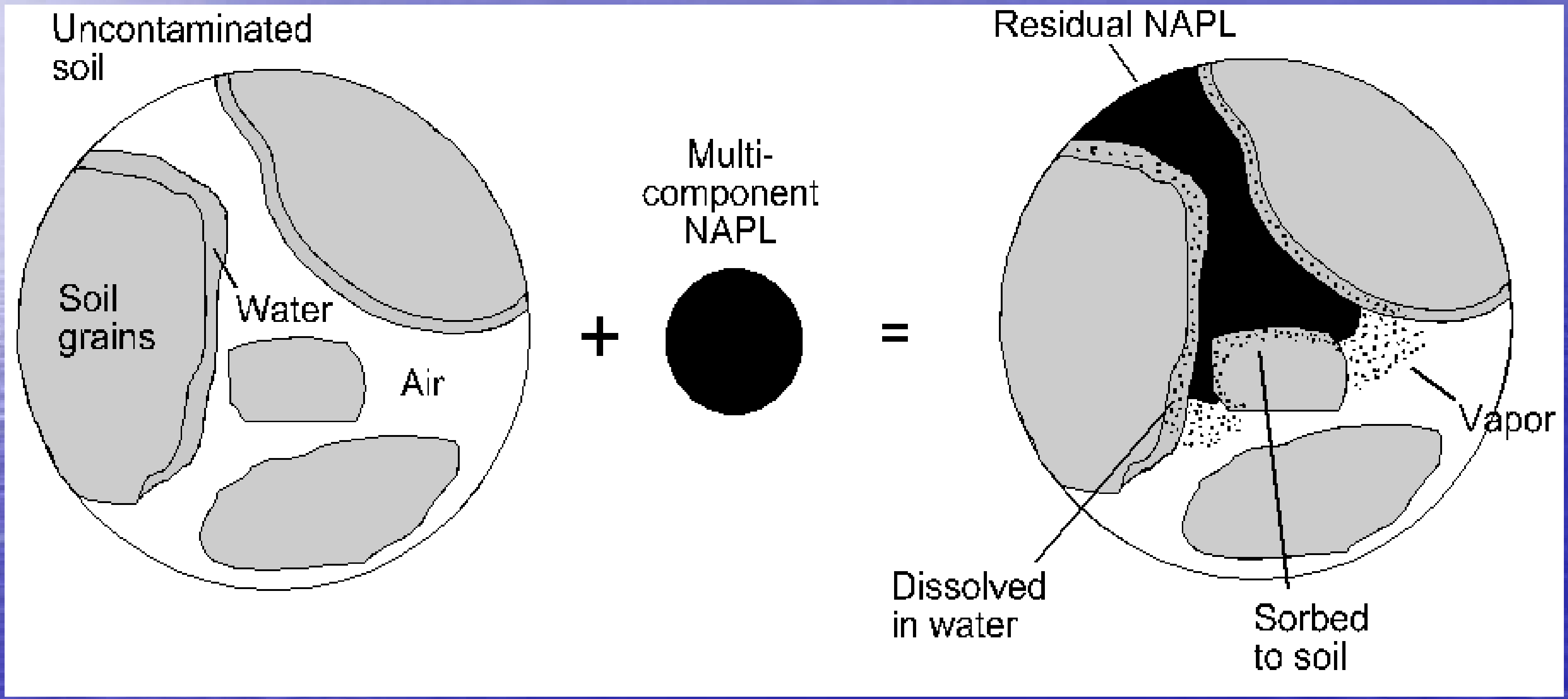


3-Phase Partitioning Equation

$$C_s = C_w (UCF) DF \left[K_d + \frac{\theta_w + \theta_a H_{cc}}{\rho_b} \right]$$

C_s = Soil concentration (mg/kg)
C_w = Groundwater cleanup level established under WAC 173-340-720 (ug/l)
UCF = Unit conversion factor (1 mg / 1,000 ug)
DF = Dilution factor (dimensionless: 20 for unsaturated zone soil, 1 for saturated zone soil)
K_d = Distribution coefficient (L/kg)
θ_w = Water-filled soil porosity (0.3 ml water/ ml soil for unsaturated zone soil; 0.43 ml soil/ml water for saturated zone soil)
θ_a = Air-filled soil porosity (0.13 ml air/ml soil for unsaturated zone soil; zero for saturated zone soil)
H_{cc} = Henry's law constant (Dimensionless)
ρ_b = Dry soil bulk density (1.5 kg/L)

NAPL Equilibrium Partitioning



4-Phase Partitioning Equation

Partitions chemical mass among four phases: soil, air, water and NAPL.

$$\frac{M_T^i}{m_{soil}} = \frac{x_i S_i}{\rho_b}\left[\theta_w + K_{oc}^i f_{oc}\rho_b + H_{cc}^i\theta_a + \frac{GFW_i}{S_i}\rho_{NAPL}\theta_{NAPL}\right]$$

M_T^i = Total mass of component in the system (mg).
m_{soil} = Total soil mass (kg).
x_i = Mole fraction (at equilibrium) of component (dimensionless).
S_I = Solubility of each component (mg/L).
ρ_b = Dry soil bulk density (1.5kg/l)
θ_w = Volumetric water content (ml water / ml soil)
K^i_{oc} = Soil organic carbon-water partitioning coefficient for each component (L/kg).
f_{oc} = Mass fraction of natural organic carbon (0.001 g soil organic / g soil)
H^i_{cc} = Henry's law constant for each component (dimensionless)
θ_a = Volumetric air content (ml air volume / ml total soil volume)
GFW_i = Gram formula weight, or molecular weight each pure component (mg/mol)
ρ_{NAPL} = Molar density of NAPL mixture (mol/l).
θ_{NAPL} = Volumetric NAPL content (ml NAPL volume / ml total soil volume)

3/4-Phase Model Input Parameters

Distribution Coefficient (Kd)

$$\mathrm{Kd} = \frac{\mathrm{Soil\ (mg/kg)}}{\mathrm{Water\ (mg/L)}} = \mathrm{L/kg} = \mathrm{ml/g} = \mathrm{cm^3/g}$$

- **Kd is a measure of the chemical mass that partitions to both the solid and liquid phases. It is used to predict chemical partitioning and to estimate retardation.**

3/4-Phase Model Input Parameters

Soil Organic Carbon-Water Partitioning Coefficient (Koc)

For Non-ionic Hydrophobic Organics

- Koc may be used in conjunction with soil foc to predict the distribution coefficient (Kd):

$$Kd = Koc * foc$$

Example: calculate benzene Kd for soil with 0.1% foc

Benzene Koc = 62 ml/g

Kd = 62 ml/g * 0.001 g carbon / g soil = 0.062 ml/g

3/4-Phase Model Input Parameters

Mass Fraction of Natural Soil Organic Carbon (foc)

- Most soils have a small amount or "fraction" of natural organic carbon.
- Soil foc is typically higher near the ground surface and decreases with depth. Common range is ≈ 0.1 - 1%.
- Units = g soil organic carbon / g soil.
- Commonly expressed as % foc
- Default value is 0.1% foc = 0.001 g organic carbon per g of soil.

3/4-Phase Model Input Parameters
Metals Kd

- The relationship between soil organic carbon and sorption is not as dominant as it is for nonionic organics.

- Soil texture (grain size), pH, iron oxide content etc. also control metals sorption.

3/4-Phase Model Input Parameters

Soil Porosity, Bulk Density, Volumetric Water / Air Content

- Soil porosity = void volume / total soil volume (dimensionless). MTCA default = 0.43

- Dry soil bulk density = mass (kg) per volume (L). MTCA default = 1.5 kg/L

- Volumetric water content = ml of water / ml of soil pore space. MTCA default = 0.3 ml / ml

- Volumetric air content = ml of air / ml of soil pore space. MTCA default = 0.13 ml / ml

3/4-Phase Model Input Parameters

Henry's Law Constant (HLC)

- Henry's law constant (HLC) is the "air-water" partition coefficient. It is the ratio of the aqueous solubility of a substance (mg/L) at a given temperature to the saturated vapor phase concentration (mg/L)

Example

•HLC = Vapor Pressure * Molecular Weight / Solubility
•Benzene = 0.125 atm * 78 g/mol / 1,780 mg/L = 5.47 E-03 atm-m3/mol
•Dimensionless (H') = (HLC [atm-m3/mol] x 41) (@ 25° C)
•H' for benzene = 0.22

3/4-Phase Model Input Parameters
Dilution Factor (DF)

- **Accounts for the dilution that occurs when soil pore water mixes with ground water**
- **Dimensionless number**
- **MTCA Defaults:**

  Above Water table = 20

  Below water table = 1

- **MTCA default DF is based on EPA Guidance & Science Advisory Board (SAB) review**

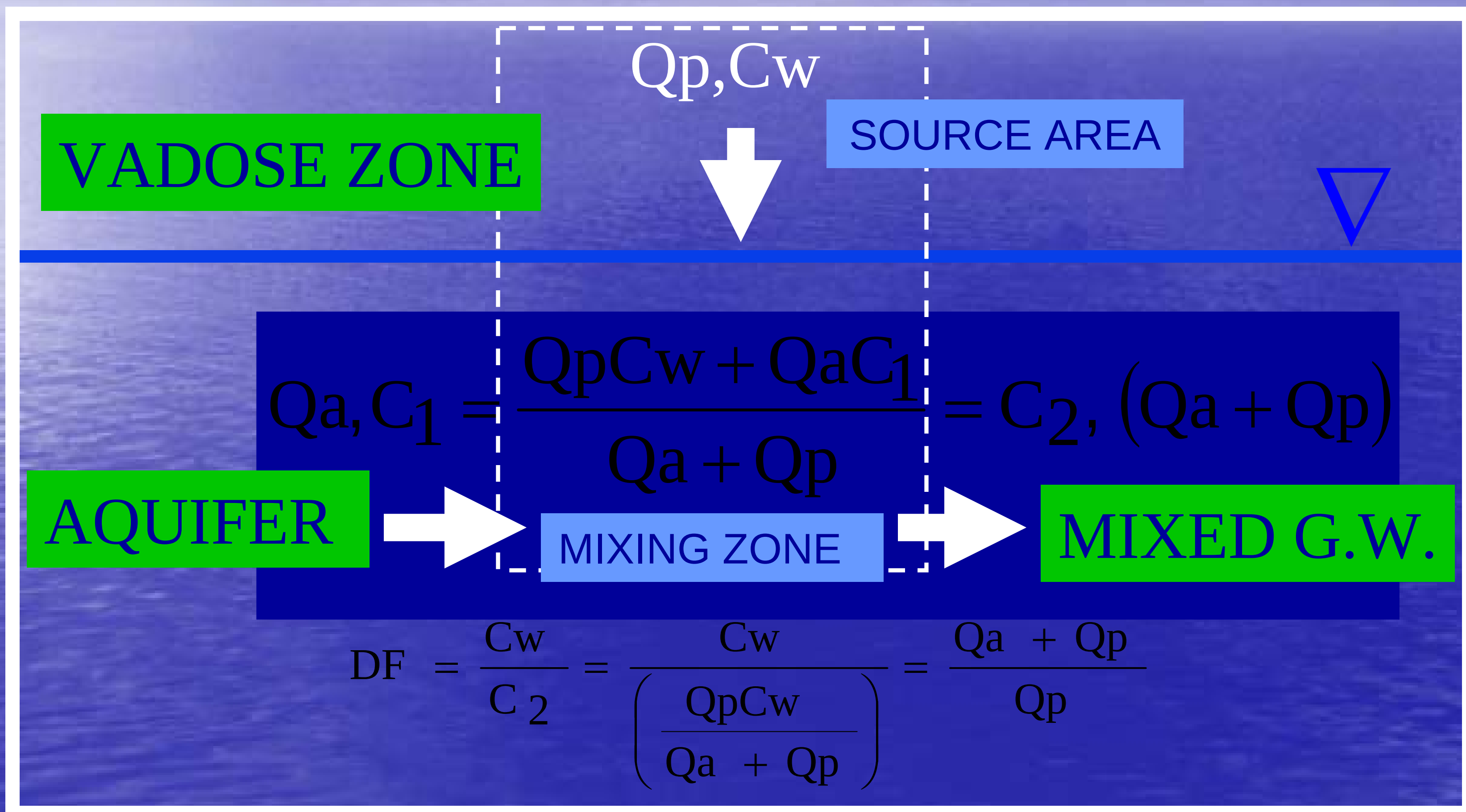
Qa = Ground Water Flow (m3/yr)

Qp = Infiltration (m3/yr)

C1 = Background Concentration (mg/L)

C2 = Concentration after Mixing (mg/L)

DILUTION FACTOR



$$Qa, C_1 = \frac{QpCw + QaC_1}{Qa + Qp} = C_2, (Qa + Qp)$$

$$DF = \frac{Cw}{C_2} = \frac{Cw}{\left(\frac{QpCw}{Qa + Qp}\right)} = \frac{Qa + Qp}{Qp}$$

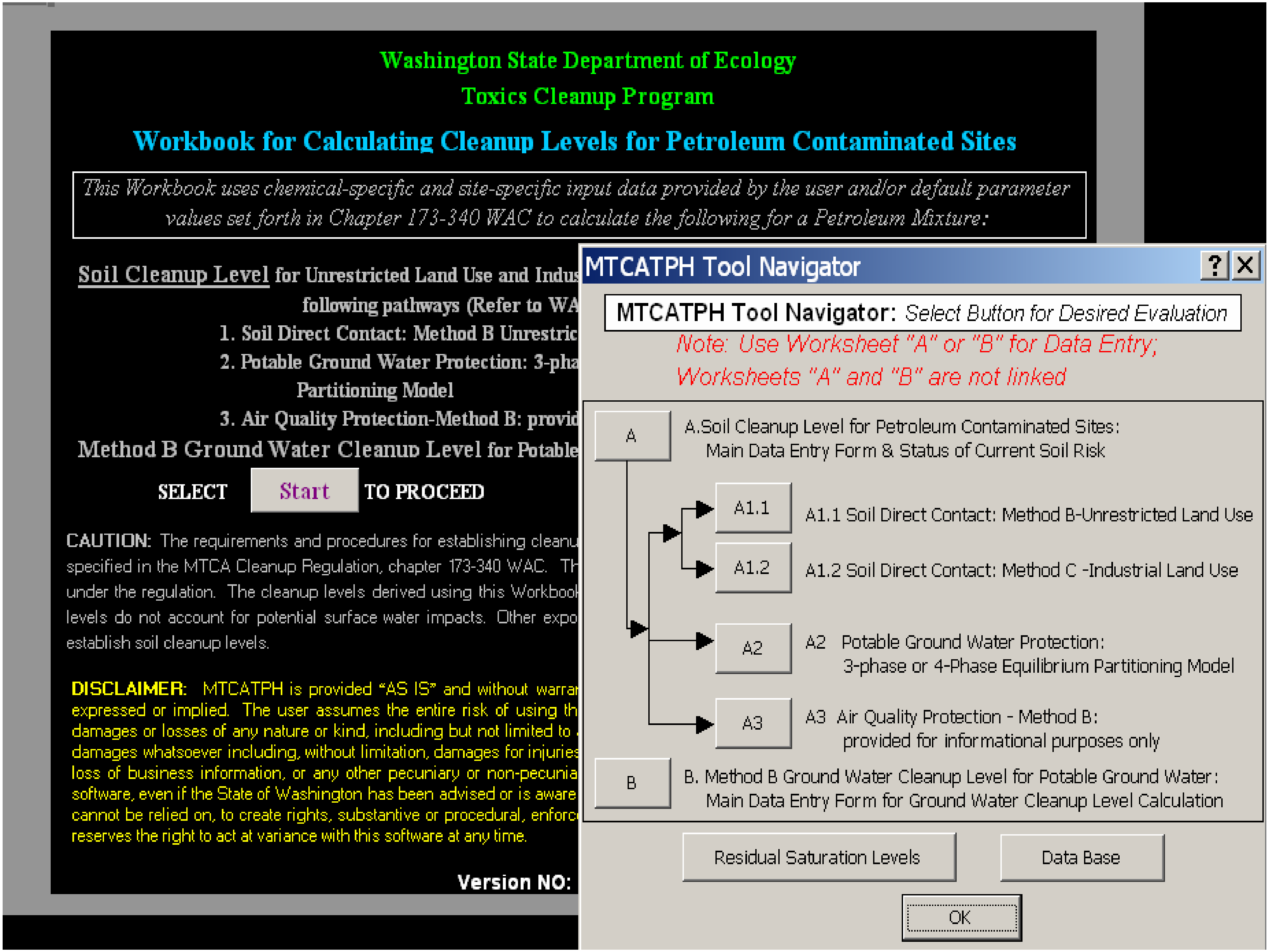
Establishing Methods B & C Soil Clean up Levels for TPH Mixtures

- Must evaluate noncarcinogenic effects of TPH mixture as a whole
- Must evaluate ARARs and carcinogenic effects for individual TPH components
- Need measured soil or product composition including TPH fractions and components
- Dermal already incorporated into equations
- May need to evaluate vapors if SSRA results in significantly higher soil cleanup levels

Workbook Tools for Calculating Soil and Ground Water Cleanup Levels under the Model Toxics Control Act Cleanup Regulation

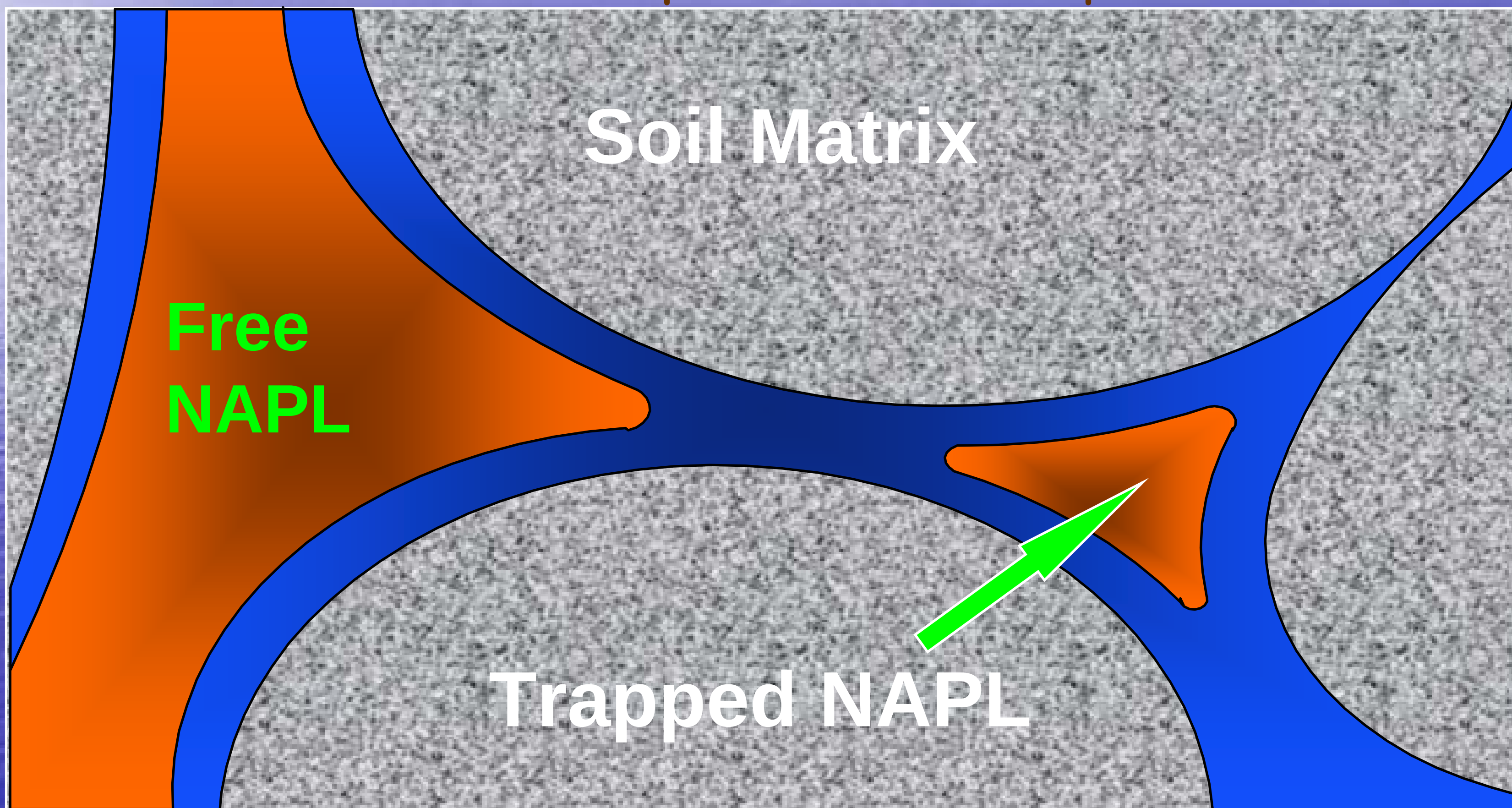
User's Guide

Washington State Department of Ecology
Toxics Cleanup Program


Washington State Department of Ecology
Toxics Cleanup Program
Workbook for Calculating Cleanup Levels for Petroleum Contaminated Sites
This Workbook uses chemical-specific and site-specific input data provided by the user and/or default parameter values set forth in Chapter 173-340 WAC to calculate the following for a Petroleum Mixture:
Soil Cleanup Level for Unrestricted Land Use and Indus
following pathways (Refer to WA
1. Soil Direct Contact: Method B Unrestric
2. Potable Ground Water Protection: 3-pha
Partitioning Model
3. Air Quality Protection-Method B: provid
Method B Ground Water Cleanup Level for Potable
SELECT
Start
TO PROCEED
CAUTION: The requirements and procedures for establishing cleanu specified in the MTCA Cleanup Regulation, chapter 173-340 WAC. Th under the regulation. The cleanup levels derived using this Workbook levels do not account for potential surface water impacts. Other expo establish soil cleanup levels.
DISCLAIMER: MTCATPH is provided "AS IS" and without warra expressed or implied. The user assumes the entire risk of using th damages or losses of any nature or kind, including but not limited to damages whatsoever including, without limitation, damages for injuries loss of business information, or any other pecuniary or non-pecunia software, even if the State of Washington has been advised or is aware cannot be relied on, to create rights, substantive or procedural, enforc reserves the right to act at variance with this software at any time.
Version NO:
MTCATPH Tool Navigator
?
X
MTCATPH Tool Navigator: Select Button for Desired Evaluation
Note: Use Worksheet "A" or "B" for Data Entry;
Worksheets "A" and "B" are not linked
A
A.Soil Cleanup Level for Petroleum Contaminated Sites:
Main Data Entry Form & Status of Current Soil Risk
A1.1
A1.1 Soil Direct Contact: Method B-Unrestricted Land Use
A1.2
A1.2 Soil Direct Contact: Method C -Industrial Land Use
A2
A2 Potable Ground Water Protection:
3-phase or 4-Phase Equilibrium Partitioning Model
A3
A3 Air Quality Protection - Method B:
provided for informational purposes only
B
B. Method B Ground Water Cleanup Level for Potable Ground Water:
Main Data Entry Form for Ground Water Cleanup Level Calculation
Residual Saturation Levels
Data Base
OK

Residual Saturation

NAPL = Non Aqueous Phase Liquid



Residual Saturation (RS) Section 747 (10)

- RS is a term that is used to describe the phenomena that occurs when NAPL gets "trapped" in soil
- RS is primarily a function of soil grain size & moisture content, as well as the viscosity of the NAPL itself
- RS default values for TPH are in Table 747-5
- May develop site-specific screening levels
- May conduct an empirical demonstration

Leaching Tests: Section 747 (7)

- EPA Method 1311 (TCLP) & EPA Method 1312 (SPLP) leaching tests may be used to derive protective soil concentrations for the following metals: arsenic, cadmium, total / hexavalent chromium, copper, lead, mercury, nickel, selenium and zinc.
- Other leach tests may be used on a site-specific basis for other hazardous substances, per Ecology approval.

Alternative Fate / Transport Models: Section 747 (8)

- Mathematical algorithms that simulate the fate and transport of hazardous substances in soil and ground water may be used
- Finite source assumption and biodegradation may be used
- Model assumptions, input parameters and values subject to the criteria specified in Section 702 (New Scientific Information)

Empirical Demonstration: Section 747 (9)

- Empirical = relying upon or derived from observation or experiment, i.e. site-specific data
- One or any combination of the methods described in Section 747 may be used
- Criteria = you must demonstrate that the soil / ground water system has achieved steady-state or equilibrium conditions. Methods used must also comply with the criteria specified in Section 702 (New Scientific Information)

Establishing Soil Point of Compliance Under WAC 173-340-740 & 745